Lidar Hard Target Calibration: Preliminary Study of Reference Materials for 2μm Lidars

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in atmospheric remote sensing - particularly Doppler lidar wind sensing and water vapor profiling by differential absorption lidar - there is considerable interest in the potential use of eyesafe solid-state laser transmitters based on the holmium $^5I_7$-$^5I_8$ transition at 2μm. This has gained momentum by recent advances in laser development such as ±1MHz frequency stability [1,2] from a diode-pumped cw laser at room temperature. In support of such applications, it is frequently desirable to determine the absolute backscatter values within the atmospheric airmass being probed. In order to elicit this information, it is imperative that these instruments be calibrated regularly using targets with known surface reflectivity characteristics. Consequently, a clear need has been recognized to establish a broad and reliable data base of surface properties of candidate calibration target materials (field, transfer and standard) at wavelengths around 2pm using established hard target calibration methodology '3). Presented here is a preliminary study of the retroreflection function of several such candidate materials obtained - with polarization sensitivity included. These data were obtained using a retroreflection configuration when illuminated by a diode laser-pumped Tm,Ho:YLiF$_4$ laser at a wavelength of 2pm.

The volume backscattering coefficient, $\beta(m^{-1}.sr^{-1})$, is related to the target reflectance parameter, p', for a coaxial lidar configuration by(3):

$$\beta(R_b) = \frac{P_b(t)}{E_{tb}} \frac{E_{ts}}{I_s} \rho^* \frac{O(R_s)}{O(R_b)} \frac{2}{c} \frac{R_b^2}{R_s^2} \cdot \frac{\exp\left[-2\int_o^{R_s} \alpha_s(R')dR'\right]}{\exp\left[-2\int_o^{R_b} \alpha_b(R')dR'\right]}$$

where: E_{ts}, E_{tb} are the transmitted energy for target scattering and backscattering (J), I_s is the time integral of the target return signal (J), $P_b(t)$ is the receiver power at time t due to backscatter (W), O(R) is the transmitter/receiver overlap function for a particular lidar system, $R_{s,r}$ are the ranges to the hard target and to the backscatter volume (m) and $\alpha_{s,b}$ arc the extinction coefficients of the atmosphere appropriate to the measurement (m-').

The reflectance parameter which connects a given lidar system with the lidar community standard, via the hard target methodology, is obtained using the monostatic reflectometer where the functional dependence are expressed by:

$$\rho^*(FT,LB,hH) = \frac{G(FT,MR,hH)}{G(TT,MR,hH)+G(TT,MR,hV)} \cdot \frac{G(TT,IS,hU)}{G(ST,IS,hU)}$$

$$\cdot\, \rho\,(ST,',IS,hU)\, k_1 k_2 \cos\phi/\pi$$

where G( ) is the signal, FT, TT and ST are the field, transfer and standard targets respectively, hH describes the polarization state (i.e. incident and reflected; horizontal), IS is the integrating sphere, MR the monostatic reflectometer, ϕ is the angle of incidence and $K_{1,2}$ are the optical correction factors. It is important that the reflectance properties of all three targets; field, transfer and standard, are fully characterized with respect to retro-reflection, specular reflection and also to polarization, An experiment designed to realize these objectives is described below.

The arrangement of apparatus is shown in Fig.(1). The 2μm laser source is a diode-laser pumped $Tm,Ho:YLiF_4$ laser operated at room temperature with typical CW output power of 50mW in the fundamental spatial mode, The laser is linearly polarized parallel to the plane of incidence and, for the purposes of these experiments can be rotated using a zero-order half waveplate. In all cases the targets are mounted on a rotating disk (to reduce speckle) with the target normal orientated with $\pm 0.5°$ resolution relative to the incident wavevector. The HgCdTe photodetector was mounted on a rotatable arm and scanned about a vertical axis through the target face with the detector field of view restricted to the target face to minimize background noise and increase spatial resolution. In this initial study, the polarization vector of the incident light was parallel to the plane of incidence, with the p and s-components of the light scattered from the target distinguished using a ZnSe Brewster stack. The angular variation of reflected light was obtained by steadily rotating the photodetector while recording the scattered light for each target material, the scattered SNR being enhanced using a chopper and lock-in amplifier.

It was decided to concentrate on the region near the retrorefiection peak. This particular feature was analyzed for those target materials listed below with the results listed in Table 1.

Table 1. Summary of Results for P-polarization Incident

Target Material	Retroreflection Po]. Case	Depolarization Ratio
Sulfur, CS_2	P	0.90
Sulfur, acetone	P	0.92
$SrCO_3$, acetone	P	0.67
Styrofoam, HD	p	0.85
Spcctroflext, Labsphere	P, S(small)	0.83
Gold Std., Labsphere	P, s	0.19
Al, flame sprayed	P, S	0.24
Al, sandblasted	P, s	0.27

The middle column of Table 1 lists the polarization case (parallel or perpendicular to the plane of incidence) of the reflected radiation at the retroreflection peak. Also shown in the right column is the depolarization of the diffuse reflectance adjacent to the retro peak.

This introductory study shows that those hard target materials which until now have been used in the lidar calibration at CO_2 wavelengths (9-1 1μm) exhibit generally similar reflectance characteristics at wavelengths around 2pm. At this stage of the analysis, the flowers of sulfur again appears to be a promising surface for use as a reference target since it is the best approximation to a Lambertian surface[4,5]. The roughened metal surfaces which exhibit retroreflection in both polarizations will be characterised in detail as possible field targets.

This work and the results of our continuing activity directed towards the measurement of the reflectance characteristics of target materials will be presented and discussed further.

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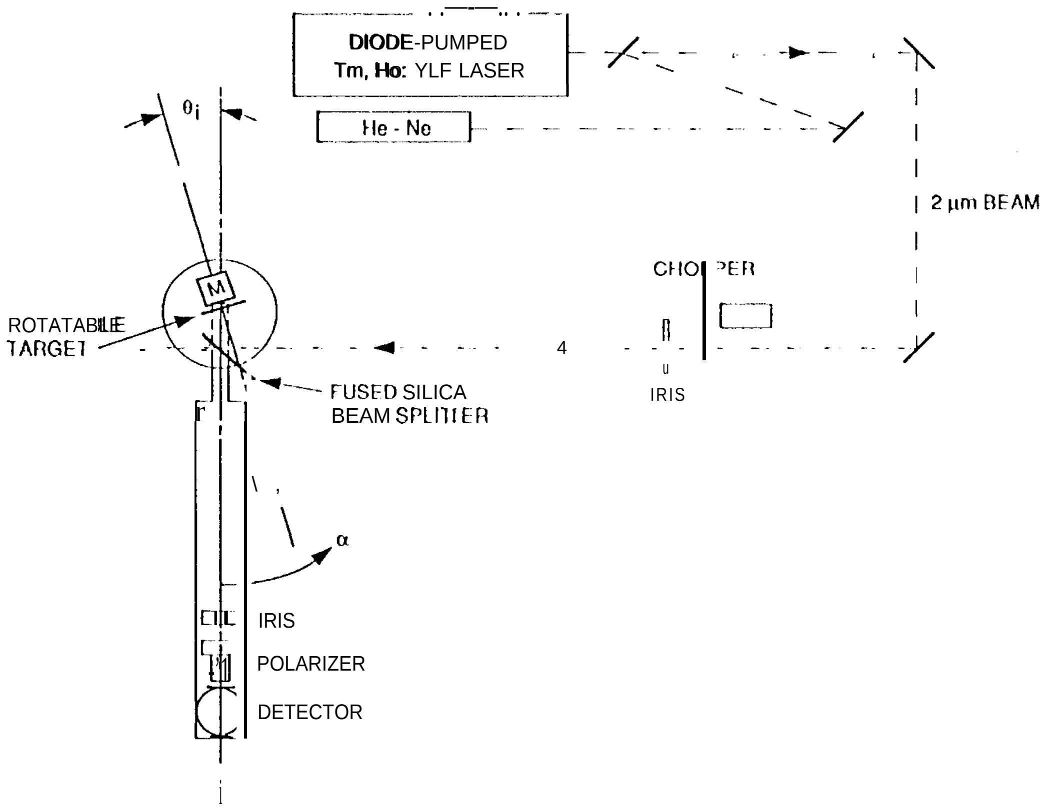

Fig.(1). The optical layout used throughout this study. This is the JPL target calibration facility modified to employ the diode laser pumped Tm,Ho:YLF laser at 2μm.

References:

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